FOREST STRUCTURE CHARACTERIZATION USING JPL'S UAVSAR MULTI-BASELINE POLARIMETRIC SAR INTERFEROMETRY AND TOMOGRAPHY

Maxim Neumann, Scott Hensley, Marco Lavalle, Razi Ahmed

Jet Propulsion Laboratory, California Institute of Technology

Radar Science and Engineering Section

4800 Oak Grove Dr, Pasadena, CA 91109

ABSTRACT

This paper concerns forest remote sensing using JPL's multi–baseline polarimetric interferometric UAVSAR data. It presents exemplary results and analyzes the possibilities and limitations of using SAR Tomography and Polarimetric SAR Interferometry (PolInSAR) techniques for the estimation of forest structure. Performance and error indicators for the applicability and reliability of the used multi-baseline (MB) multi-temporal (MT) PolInSAR random volume over ground (RVoG) model are discussed. Experimental results are presented based on JPL's L-band repeat-pass polarimetric interferometric UAVSAR data over temperate and tropical forest biomes in the Harvard Forest, Massachusetts, and in the La Amistad Park, Panama and Costa Rica. The results are partially compared with ground field measurements and with air-borne LVIS lidar data.

1. INTRODUCTION

Synthetic Aperture Radar (SAR) remote sensing provides several paradigms to estimate forest structure parameters, including vertical structure and biomass. Polarimetric backscatter measurements can be used to get a rough estimate of biomass, up to a frequency dependent biomass saturation level, and to detect changes in vegetation. More accurate biomass estimates are possible when vegetation structure information is available, e.g., vegetation height or diameter at breast height (DBH). Radar can obtain vegetation structure information by collecting polarimetric and interferometric (PolInSAR) observations or multi-baseline (MB) observations that can be employed using standard PolInSAR or tomographic techniques to estimate vegetation structure. In this paper, we present forest structure

estimation results using the advanced MB-PolInSAR and Polarimetric SAR Tomography techniques, analyzing the performance and quantifying the error sources. The experimental data is acquired by JPL's UAVSAR (Uninhabited Aerial Vehicle SAR).

UAVSAR is a NASA/JPL L-band polarimetric interferometric synthetic aperture radar employing an electronically scanned array. The radar is housed in a pod mounted to the fuselage of a Gulfstream III jet. Nominally, the aircraft flies at an altitude of 12.5 km and maps a 22 km swath with incidence angles ranging from 25°to 60°. The 80 MHz range bandwdith results in single look complex imagery with range and azimuth resolutions of 1.66 m and 1 m respectively. A precision autopilot allows the platform to fly withing a 5m tube along a specified trajectory, providing very accurate baseline acquisition configurations.

2. APPROACHES

The combination of a polarimetric scattering media model with an interferometric vertical structure model (in the most simple case in the random volume over ground model (RVoG)) provides the possibility to separate the ground and the volume contributions based on polarimetric signatures and interferometric coherence diversity. Using a full MB-PolInSAR scattering model enhances the estimation of the vertical forest structure parameters by enabling us to estimate the individual power contributions, the ground–to–volume ratio, the temporal decorrelation, next to the differential extinction and geometric and dielectric ground and canopy characteristics.

An alternative approach to estimate vertical forest structure profiles is to use SAR Tomography, which is an imaging approach. It requires baseline diversity and is, contrary to PolInSAR, an imaging technique, which focuses the SAR data along the vertical direction. Providing a well selected geometric baseline configuration and an accurate calibration, SAR Tomography is more robust against various system, geometric and temporal noise sources, at the expense of the necessity to acquire many more flight lines.

3. EXPERIMENTAL RESULTS

Fig. 1 shows an example of a forest height prole extracted along a transect of the Harvard Forest using 4 interferometric data sets. The average kzs for the interferometric baselines used in the height determination were between 0.03 and 0.15, corresponding to interferometric ambiguity heights of 42 to 210 meters. The temporal separations between acquisitions were up to 90 minutes. The Random Volume over Ground (RVoG) model [7] and [8] was used to decompose the MB-PolInSAR data into ground and volume layers and to estimate the canopy height from the inter-

ferometric volume coherences, taking temporal and other residual decorrelation terms into account. MB-PolInSAR tree height estimates were obtained after taking 144 looks corresponding to an area resolution of 10×15 m in slant range geometry. MB-PolInSAR Estimated vegetation heights are in rough agreement with lidar measurements and have an RMSE of about 3 m. As an example, a Capon tomogram over the same data transect is shown in Fig. 1.(c-d), confirming the MB-PolInSAR forest height estimates.

Acknowlegement

The research described in this paper was carried out in part at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

4. REFERENCES

[1] S. R. Cloude and K. P. Papathanassiou, "Polarimetric SAR interferometry," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 36, pp. 1551–1565, Sept. 1998.

[2] R. N. Treuhaft and P. R. Siqueira, "Vertical structure of vegetated land surfaces from interferometric and polarimetric radar," *Radio Sci.*, vol. 35, no. 1, pp. 141–178, Jan. 2000.

[3] K. P. Papathanassiou and S. R. Cloude, "Single–baseline polarimetric SAR interferometry," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 39, pp. 2352–2363, Nov. 2001.

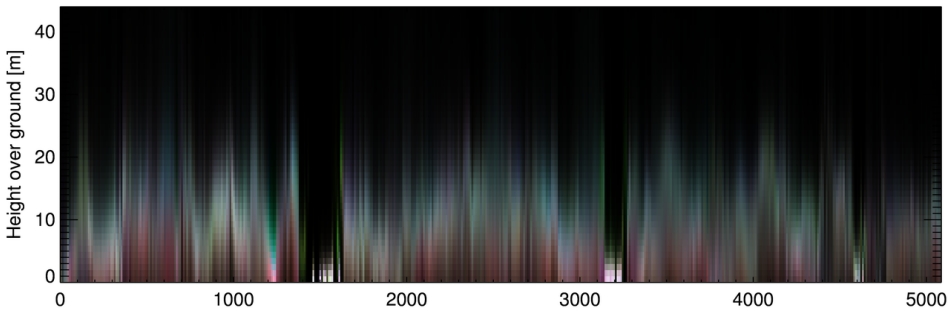
[4] S. Tebaldini, "Algebraic synthesis of forest scenarios from multibaseline PolInSAR data," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 47, no. 12, pp. 4132–4142, Dec. 2009.

[5] M. Neumann, L. Ferro-Famil, and A. Reigber, "Estimation of forest structure, ground and canopy layer characteristics from multi–baseline polarimetric interferometric SAR data," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 48, no. 3, pp. 1086–1104, Mar. 2010.

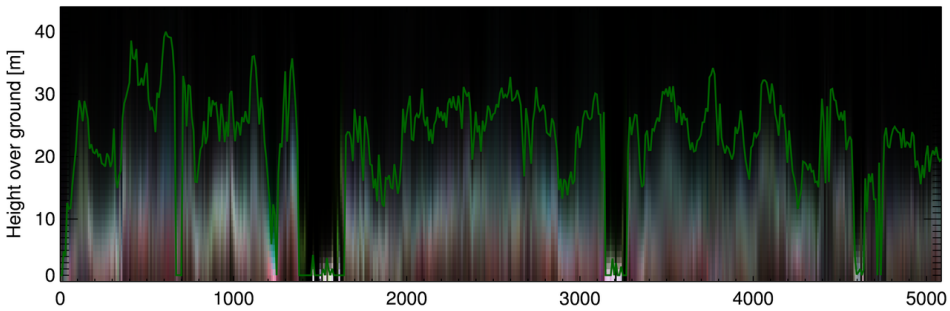
[6] S. Hensley, T. Michel, M. Neumann, M. Lavalle, R. Muellerschoen, B. Chapman, C. Jones, R. Ahmed, F. Lombardini, and P. Siqueira, "Some first polarimetric-interferometric multi-baseline and tomographic results at harvard forest using uavsar," in *Proceedings of the International Geoscience Remote Sensing Symposium (IGARSS)*, Munich, Germany, July 2012, pp. 5202 –5205.

(a) Optical image of the area with the delineated profile.

(b) SAR image of the area with the delineated profile.



(c) SAR Tomography imaging of the scene. Color coding: red – double-bounce (ground-trunk) interactions, green – diffuse (volumetric random) scattering, blue – isotropic (surface) scattering.



(d) Overlapping the independently processed forest structure estimates by PolInSAR and SAR Tomography.

Fig. 1. Example of tomographic and MB-PolInSAR forest structure estimates. Based on 4 acquisitions for both, PolInSAR and SAR Tomography. Test site: Harvard Forest in Massachusetts; PolInSAR instrument: JPL's UAVSAR.